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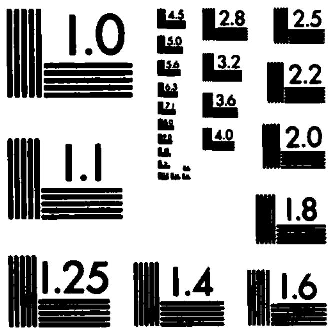


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# Comprehending Procedural Instructions: The Influence of Comprehension Monitoring Strategies and Instructional Materials

Frances L. Schorr
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Technical Report No. 10



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The two goals of this investigation were to: 1) examine the comprehension monitoring strategies adults employ when trying to comprehend procedural instructions, and 2) determine how comprehension may be affected by varying such instructions. College students using instructions that consisted of either text alone, illustrations alone, or a combination of the two, were videotaped individually as they attempted to assemble a toy loading cart. In addition to differences in the mode of presentation, the instructions were also varied

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so that half of the students received directions that contained explicit operational or "how to" information while the other half received directions that contained more general information. The videotaped performances were then coded according to a taxonomy of comprehension monitoring strategies (Schorr, 1982).

The results showed that several of these strategies were related to comprehension as measured by the speed and accuracy of performance. The findings also indicated that, regardless of the mode of presentation (i.e., pictures, text, or a combination of the two), students using instructions that contained explicit operational information made fewer uncorrected errors than those using more general instructions. Suggestions, based on these results, are offered for the design and use of procedural instructions.

## ABSTRACT

The two goals of this investigation were to: 1) examine the comprehension monitoring strategies adults employ when trying to comprehend procedural instructions, and 2) determine how comprehension may be affected by varying such instructions. College students using instructions that consisted of either text alone, illustrations alone, or a combination of the two, were videotaped individually as they attempted to assemble a toy loading cart. In addition to differences in the mode of presentation, the instructions were also varied so that half of the students received directions that contained explicit operational or "how to" information while the other half received directions that contained more general information. The videotaped performances were then coded according to a taxonomy of comprehension monitoring strategies (Schorr, 1982).

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# COMREHENDING PROCEDURAL INSTRUCTIONS: THE INFLUENCE OF COMPREHENSION MONITORING STRATEGIES AND INSTRUCTIONAL MATERIALS

Comprehending procedural instructions can, at times, be quite frustrating. These instructions are the kinds that are used for such diverse tasks as assembling models, sewing patterns, or cooking recipes. They constitute a large and important category of reading material that most adults and many children have often used.

Depending on the nature of the task, successful comprehension of such material may lead to building the hoped for model, operating a piece of equipment, or baking the appropriate pie. A good indication, then, that individuals have understood or comprehended these instructions is if they are able to achieve the desired outcome described in the directions (Gibson and Levin, 1975). Failure to comprehend such instructions may range from disappointing a child expecting a fully assembled toy on Christmas to not being able to stay abreast of the latest technological advances in one's field. Comprehension of instructional materials, then, has far reaching ramifications for the reader and yet little is known about this comprehension process or the factors that may affect it. In the present study an attempt was made to remedy this situation. Specifically, the comprehension of instructional materials was investigated by focusing on two of the factors that may affect such comprehension, namely, the reader's skills or activities and the nature of the instructional materials that they are reading.

In order to accomplish the first goal, an assessment was made of

the kinds of activities or procedures readers use as they try to comprehend procedural directions. These activities are needed to evaluate and regulate their understanding of the material. If such skills are lacking, comprehension will be impaired and performance will suffer. Individuals, then, must be able to recognize when they have failed to understand a direction and must also know what to do when such comprehension failures occur. The latter activities may involve such strategies as re-reading the material, looking ahead or simply continuing in the hope that clarification will soon be provided.

The term metacognition has been used to refer to this knowledge one has of his or her own cognitions and the regulation of those cognitions (Flavell, 1979). Examples of the self-regulatory activities include checking the outcome of the results, planning the next move, monitoring effectiveness, and testing, revising and evaluating one's strategies (Brown, 1978). Thus, understanding is related to how well a person can monitor his or her ongoing comprehension of some material. This comprehension monitoring is an important aspect of metacognition and a vital component of reading (Winograd and Johnston, 1980).

Most of the research in this area has been focused on the metacognitive ablitities of children (e.g. Brown, 1975, Flavell and Wellman, 1977). In comparison, the literature dealing with metacognition in adults is not as abundant. While several studies have found differences in the comprehension monitoring skills of mature readers (Thorndyke and Stasz, 1980; Baker, 1980), relatively little research has explored this issue in adults. Few investigations have

been conducted to assess the kinds of comprehension monitoring strategies adults employ when reading. In a recent study, however, the various strategies these readers use when trying to comprehend one type of reading material, procedural instructions, were identified and categorized in a taxonomy of comprehension monitoring strategies (Schorr, 1982). One of the goals of the present study was to determine if such strategies, shown in Table 1, are related to successful comprehension.

In addition to this first goal of examining the reader's skills or monitoring activities, a second goal of the present study was to examine the effects of varying the instructional materials on the reader's comprehension. There are several attributes of these reading materials that may affect comprehension. Organization, semantic content, structural organization, and modality have all been found to influence a reader's understanding (Stone, 1980). Many of the studies in this area, especially those dealing with modality, have yielded contradictory findings. An example of this is the research aimed at comparing the comprehension of procedural information presented in text alone, pictures alone, or both pictures and text. While results of some studies indicate that the use of text leads to better comprehension, as measured by the accuracy of performance (Booher, 1975; Fleming, 1979), results of other studies suggest that either pictures alone (Crandell and Glock, 1981) or a combination of pictures and text (Stone and Glock, 1981) are more helpful.

One explanation for these discrepant findings is based on the

TABLE 1

A Taxonomy of Comprehension Monitoring Strategies

A. Planfulness

1. Initial approach to instructions
2. Selection of parts

B. Ways of Following the Instructions

1. Display concern with detail
2. Check work after completion

C. Detection of Errors

D. Reactions to Mistakes or Problems (Remedial Strategies)

1. Examine the construction vs. take it apart immediately
2. Examine instructions subsequent to the problem
3. Examine instructions preceding the problem
4. Reexamine the same instruction continuously
5. Experiment with the parts
6. Hypothesize; reason
7. Build another part of the assembly
8. Examine the sheet depicting the parts
9. Compare two instructions
10. Replace one part with an identical part
11. Rebuild the problem area in exactly the same way

information contained in the various sets of instructions. Until recently, however, there was no way to identify such information. In order to remedy this problem, Bieger and Glock (1982a) developed a taxonomy of the kinds of information available in procedural instructions. Applying this taxonomy, Bieger and Glock found that differences in the information content of either pictures or text exist, and these, in turn, can affect comprehension.

It is possible, then, that the contradictory findings relating to comprehension and presentation mode may be attributed to differences in the information content. In previous studies, certain kinds of information might have been more explicitly specified in either the text or the illustrations. For example, if the text included specific information on how to perform certain operations and the pictures displayed more general information, use of the text would have probably led to greater accuracy. On the other hand, if the pictures included the more explicit information then they might have been associated with more accurate performance. Thus, in the present study, it was hypothesized that readers using instructions containing explicit information would comprehend this material better than those using more general instructions.

In order to test this hypothesis, one specific kind of information, the operational or the "how to" information, was chosen to be systematically varied in different sets of directions. Bieger and Glock (1982a) have found that this particular category of information is one of three categories which include the necessary and sufficient

information for the successful completion of an assembly task.

## Method

### Subjects

Sixty-eight students, 41 females and 27 males, participated in this study. All were volunteers recruited from several introductory psychology courses taught at Cornell University.

### Equipment and Materials

The equipment included a JVC Model G-71USJ color video camera and a JVC Model HR-2200U portable color video cassette recorder. An RCA Model TC1440B video date generator was connected to this equipment enabling the date and time to appear as part of the video signal. In this way, a continuous record of the subjects' assembly times was displayed on the television monitor.

The materials consisted of parts from the Fisher-Technik 100 model kit and sets of printed instructions for the construction of a toy loading cart. The Fisher-Technik kit is composed of colorful, plastic pieces that slide or snap together. When assembled, the toy loading cart is approximately 6.5 in. (16.51 cm) tall, 2.5 in. (6.35 cm) wide, and 2.5 in. (6.35 cm) deep.

The instructions included 16 individually mounted directions that were based on those created by Stone et al. (1981). However, unlike the Stone et al, instructions, the directions used in the present study were made to differ not only with respect the mode of presentation (i.e.

pictures, text, or a combination of the two), but also with respect to the amount of detailed operational information they contained. Since three modes of presentation and two levels of operational information were varied, six sets of instructions were needed. As in the Stone et al. study, the three modes consisted of pictures alone, text alone, and a combination of both pictures and text. The levels of operational detail included an explicit or precise category and a less specific or general category. Thus, the operational information in half of the sets of instructions was explicit while the operational information in the other half was more general. In order to select appropriate instances of these levels, a preliminary analysis was undertaken to assess possible words and pictures that could be used to convey different degrees of operational information.

Using the sets of instructions designed by Stone et al., 12 gr,.uate students were asked individually to judge the explicitness of various words that had been rated by a group of undergraduates as providing operational information. Based on a consensus among raters, two sets of textual instructions were then constructed. The set containing words rated as providing more explicit operational information is shown in Figure 1 while the other set containing words judged to be more general is depicted in Figure 2.

In order to determine different levels of operational information in the pictorial instructions, two sets of 16 illustrations, based on those used by Stone et al. were drawn. In the explicit set, newly introduced parts were depicted near to but not on their final location.

1. To build column: Connect three large blocks end to end. Attach a small block to the tab end of this structure.

2. To build column: Connect three other large blocks end to end. Attach the other small block to the tab end of this structure.

3. To form the back: Arrange the columns so that they are parallel with each other. They should be about the width of two blocks apart. (Be sure that the tabs at the end of each column point in the same direction.)

4. Connect the two columns by inserting four flat pieces between them. Slide each flat piece into place using the side grooves in the blocks. (All flat pieces should have their smooth sides on the same side.) They must be flush with the ends of the columns without tabs.

5. To build the axle assembly: Fasten one angle block to the end groove of column one and fasten the other angle block to the end groove of column two. (Be sure that the tabs of the angle blocks face the same direction as the smooth sides of the back.)

6. Slide the long rod through the two angle blocks.

7. To build the base: Fasten two large blocks end to end to form a short column. Attach a third large block to a flat piece by sliding the flared edge of the flat piece into a side groove of the block. (Be sure that the ends of the flat piece are flush with the ends of the block.)

8. Attach another large block to the other flared edge of the flat piece in the same way. (Be sure that the tabs of the blocks point in the same direction.)

9. Slide these two tabs into a side groove of the short column so that the side of the short column covers the ends of both large blocks and the end of the flat piece.

10. To attach the base to the axle assembly: Notice that the base has a column of two large blocks. One side of this column has a flat piece attached to it. Attach the opposite side of this column to the exposed tabs of the axle assembly. Be sure that the flat piece in the base has its smooth side up.

11. To form the wheel assemblies: Slide a washer over each end of a long rod so that they are flush with the angle block.

12. Slide a screw hub over each end of the long rod so that their threads point away from the angle blocks.

13. Next, slide a tire over each end of the rod. Next, slide a nut hub over each end of the long rod with their wings away from the screw hub. Screw the nut hubs and screw hubs together with the tires between them. Finally, slide a washer over each end of the long rod so that they are flush with the screw hubs.

14. To form handle one: Slide a short rod through a clip so that the clip is in the middle of the rod.

15. To form handle two: Slide another short rod through andother clip so that the clip is in the middle of the rod.

16. Next, the handles should be inserted in the end of the back with exposed tabs. Each handle should be inserted in the grooves at the front of the back so that the clips are resting against the ends of the blocks. The openings on one side of each clip should fit over the tabs at the ends of the columns. This completes the assembly of the loading cart.

Figure 1: Explicit Text

1. To complete column one: Assemble three large blocks end to end. Add a small block to the tab end of this structure.

2. To complete column two: Assemble three other large blocks end to end. Add the other small block to the tab end of this structure.

3. To create the back: Move the columns so that they are parallel with each other. They should be about the width of two blocks apart. (Be sure that the tabs at the end of each column point in the same direction.)

4. Attach the two columns by moving four flat pieces between them. Arrange each flat piece into place using the side grooves in the blocks. (All flat pieces should have their smooth sides on the same side.) They must be flush with the ends of the columns without tabs.

5. To create the axle assembly: Arrange one angle block on the end groove of column one and arrange the other angle block on the end groove of column two. (Be sure that the tabs of the angle blocks face the same direction as the smooth sides of the back.)

6. Locate the long rod through the two angle blocks.

7. To create the base: Assemble two large blocks end to end to complete a short column. Add a third large block to a flat piece by moving the flared edge of the flat piece into a side groove of the block. (Be sure that the ends of the flat piece are flush with the ends of the block.

8. Add another large block to the other flared edge of the flat piece in the same way. (Be sure that the tabs of the blocks point in the same direction.)

9. Move these two tabs into a side groove of the short column so that the side of the short column covers the ends of both large blocks and the end of the flat piece.

10. To add the base to the axle assembly: Notice that the base has a column of two large blocks. One side of this column has a flat piece attached to it. Slide the opposite side of this column onto the exposed tabs of the axle assembly. Be sure that the flat piece in the base has its smooth side up.

11. To create the wheel assemblies: Arrange a washer over each end of a long rod so that they are flush with the angle block.

12. Fasten a screw hub over each end of the long rod so that their threads point away from the angle blocks.

13. Next, arrange a tire over each end of the rod. Next, arrange a nut hub over each end of the long rod with their wings away from the screw hub. Adjust the nut hubs and screw hubs together with the tires between them. Finally, arrange a washer over each end of the long rod so that they are flush with the screw hubs.

14. To create handle one: Move a short rod through a clip so that the clip is in the middle of the rod.

15. To create handle two: Move another short rod through another clip so that the clip is in the middle of the rod.

16. Next, the handles should be moved into the end of the back with exposed tabs. Each handle should be moved into the grooves at the front of the back so that the clips are resting against the ends of the blocks. The openings on one side of each clip should fit over the tabs at the ends of the columns. This completes the assembly of the loading cart.

Figure 2: General Text

Arrows were also included in these pictures as a means of showing where the parts were to fit. In the general set of illustrations, newly introduced parts were depicted in place. That is, a finished assembly was shown for each of the 16 pictures. The variations in these two sets of illustrations were chosen to reflect evaluations obtained from a sample of eight undergraduates.

After the new illustrations were drawn, two graduate students and one professional illustrator rated the explictness of the operational information included in both sets of instructions. Their evaluations and suggestions were then used to create the final versions of the explicit and general sets of illustrations shown in Figures 3 and 4 respectively.

## Procedure

The students were briefed about the study and tested in a small, quiet room. To insure that all face and hand movements would be adequately recorded, each performed the task seated at a large desk positioned in front of a camera. The experiment then proceeded as follows.

1. Each student randomly received one of the six sets of instructional materials. All were told that they were going to build a model and could use the directions provided in any way that they wished. In addition, they were also given a separate sheet depicting the various parts and the names of those parts.

2. Since verbalization has not been found to affect performance on

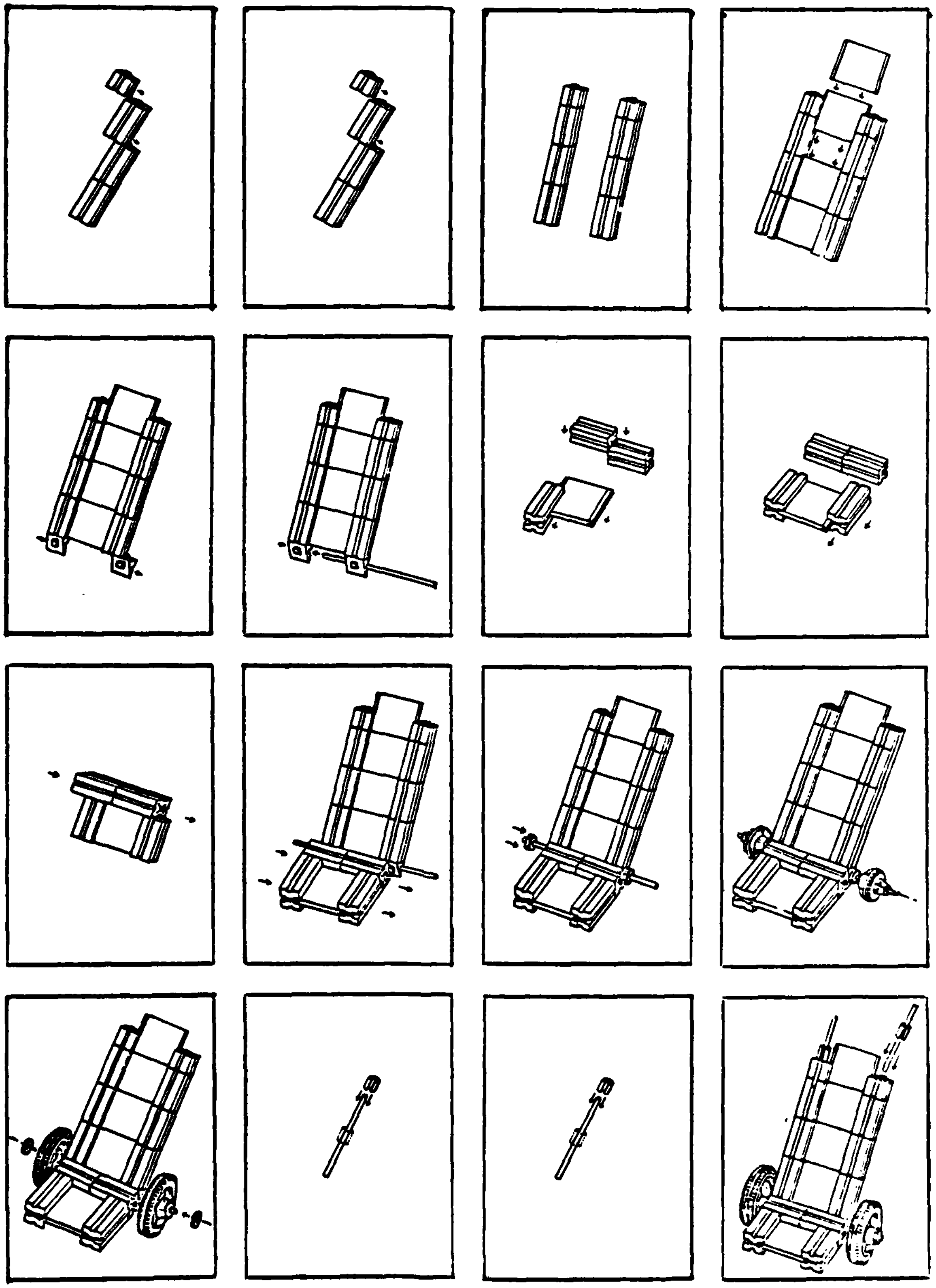


Figure 3: Explicit Illustrations

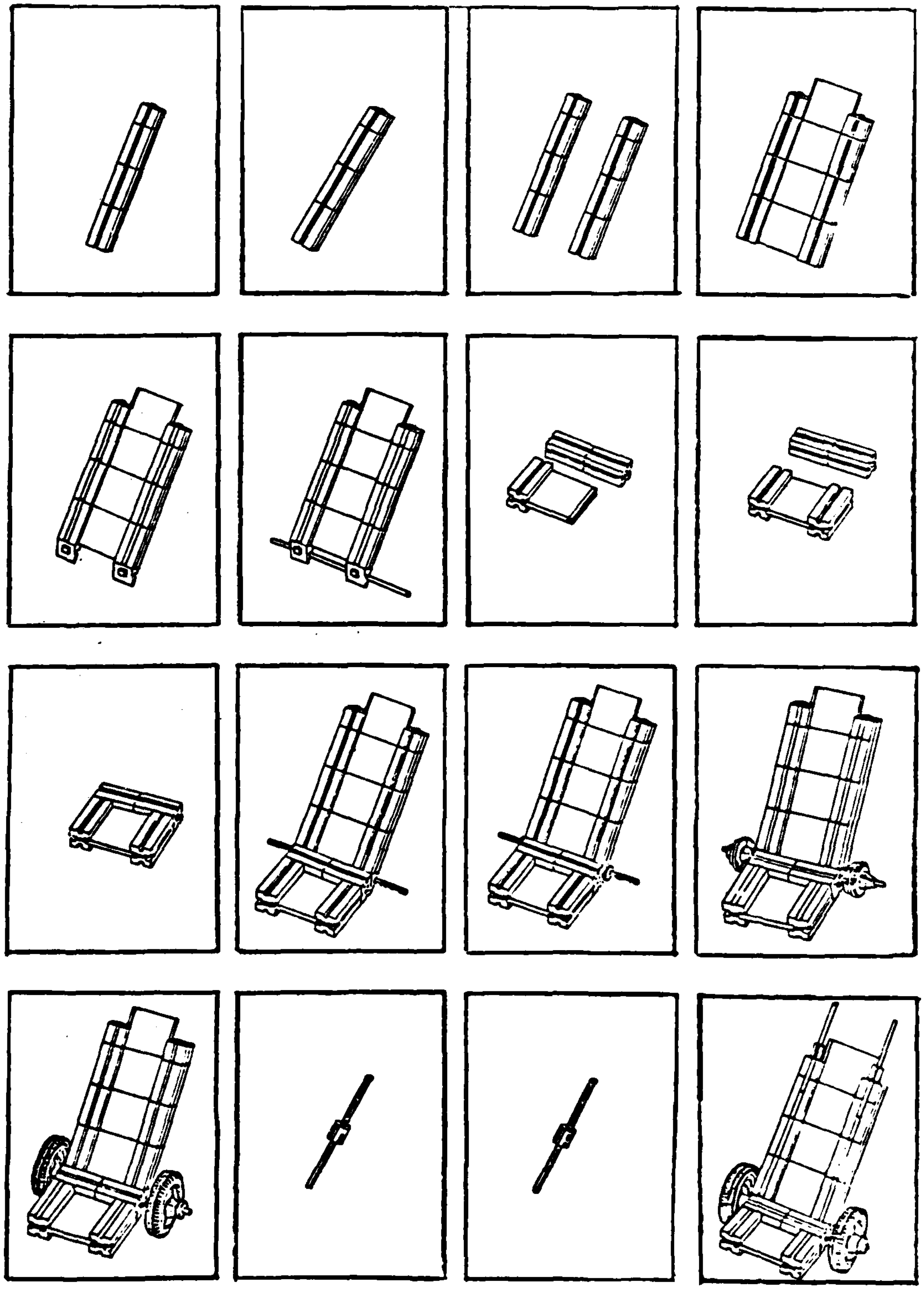


Figure 4: General Illustrations

this task (Schorr, 1982), the subjects in the present study were asked to talk about what they were doing and why they were doing it. In order to accustom them to this idea of 'thinking out loud', all were requested to attempt a practice task before beginning the assembly of the loading cart.

3. They were then videotaped individually as they performed the main assembly.

4. After the completion of the task, each student was interviewed and thanked for participating.

## Scoring

The subjects' videotaped responses were coded individually according to the taxonomy of comprehension monitoring strategies, presented in Table 1. Thus, a subject's performance was scored for each of the four major categories of the taxonomy and their various subsets. For the first two categories, scores ranging from 1 to 3 were used with a 1 indicating the lowest, and a 3, the highest degree of strategy use. For example, in the case of initial planfulness, a score of 1 was assigned to those subjects who showed little pre-planning behavior; a score of 2 was assigned to those who showed a moderate degree and a score of 3 was given to those who demonstrated a great deal of such pre-planning activities. Selection of parts, concern for detail, and checking one's work were all scored in a similar fashion.

Coding of the third category, detection of errors, depended upon a subject's detection of his or her mistakes. Making an error, therefore,

was a necessary condition for this detection to occur. Thus, only those subjects who made at least one corrected or uncorrected error were coded for this category of the taxonomy. A score of 1 was assigned to those subjects who were either slow or failed to detect their errors, while a score of 2 was assigned to those who were quick to notice their mistakes.

By coding the first three categories in this way, subjects were given one score for each of the following: initial planfulness, selection of parts, concern for detail, checking one's work and detection of errors. Ratings of the fourth category, remedial activities, were made in a different manner.

The remedial procedures were assessed at 13 predetermined points or subassemblies. These subassemblies corresponded roughly to the 16 instructions that were used in the study. The reduction in number, from 16 to 13, was the result of coding a subject's responses to several related instructions as a unit. The remedial strategies observed during each subassembly and the number of times these strategies were used were noted on the scoring sheets. Finally, in addition to tne assessment of comprehension monitoring strategies, a record was also made of the amount of time each subject took to complete the task and the number of errors he or she left uncorrected.

## Results

### Comprehension Monitoring

Correlations were computed between each of the four categories of

the taxonomy and two measures of successful performance: time to completion (speed) and the number of uncorrected errors left at the end of the assembly (accuracy). From the results of these analyses, shown in Table 2, it is evident that the first category of the taxonomy, planfulness, did not show much of a relationship to performance. There was only significant finding for this category: students who were judged to be more planful in the ways in which they selected the parts took longer to complete the task than students who were judged less planful. None of the other correlations was significant. Thus, those who completed the assembly in a relatively short amount of time did not show more initial planfulness that those who took a longer time to finish the task. In addition, students who made few errors were not any more planful, either initially or in their selection of parts, than those who made a greater number of mistakes.

While the students' planfulness showed little relationship to comprehension, as measured by the two performances scores, significant correlations were found for both their care in following the instructions and their speedy detection of errors. For example, significant correlations were found for each of the two subsets of the second category, ways of following the instructions. Students who showed a concern for detail, a strategy included in the first subset of this category, made fewer errors and took longer to complete the assembly than students who did not display this concern. Similarly, students who checked their work, a strategy involved in the second subset, made fewer errors and took more time to complete the task than

TABLE 2

Correlations Between Categories of the Taxonomy

and Task Performance Measures

| STRATEGY | TIME | UNCORRECTED ERRORS |
|---|---|---|
| Planfulness | | |
| 1. Initial Approach to Instructions | r = -.004 | r = -.077 |
| 2. Selection of Parts | r = .280* | r = -.148 |
| Ways of Following the Instructions | | |
| 1. Concern for Detail | r = .277* | r = -.208* |
| 2. Checking | r = .342** | r = -.427*** |
| Detection of Errors (N = 65) | r = .123 | r = -.527*** |
| Remedial Strategies | | |
| 1. Number of Strategies | r = .818*** | r = .119 |
| 2. Number of Different Kinds of Strategies | r = .492*** | r = .002 |

*$p < .05$
**$p < .01$
***$p < .001$

those who did not check.

Significant correlations were also found for the third category of the taxonomy, detection of errors. Those who detected their mistakes quickly made fewer errors than those who were slower to notice such mistakes. Nevertheless, this speedy detection was not related to longer performance times. Subjects who were efficient detectors took just as long to finish the task as those who were less efficient.

In order to determine the relationship between successful performance and the fourth category of the taxonomy, reactions to mistakes or problems (remedial strategies), correlations were computed between each of the two measures of success (i.e. speed and accuracy) and two measures of remedial strategy use: the total number of strategies and the number of different kinds of strategies used. The results showed that while those who employed a large number of remedial strategies took significantly more time to complete the task, they did not make any fewer or more mistakes than those who used a smaller number of such strategies. Similarly, subjects who used many different kinds of remedial activities took more time but did not differ with respect to the number of errors made than those who used less of a variety of activities.

## Effects of Varying the Instructions

The hypothesis that the inclusion of explicit operational information in procedural instructions will facilitate comprehension was tested by performing a two factor ANOVA (2x3 design) for each of the

two measures of comprehension: number of errors made and time to completion. In order to support this hypothesis, significant main effects of operational information would have to be found. As shown in Table 3, there was a significant main effect of operational information on the accuracy of students' performance ($F = 22.83$, $p<.001$). This finding indicates that college students using explicit instructions made fewer errors than students using the more general instructions. On the other hand, as presented in Table 4, the main effect of operational information on time was not significant. The overall assembly time for students using explicit instructions was no different from the overall assembly time for students using the more general directions.

One factor that was found to affect assembly time, however, was the mode of instructional presentation. The significant main effect of presentation mode on the speed of performance, shown in Table 4, indicates that subjects using instructions containing either pictures, text, or a combination of the two took significantly different amounts of time to complete the task. The Tukey method of multiple comparisons was used to determine which presentation modes were different from the others.

The analysis showed that, regardless of the level of operational detail, subjects given the text only took significantly longer to perform the task than subjects given both the pictures only ($q = 9.06$, $p<.01$), and pictures and text combined ($q = 7.09$, $p<.01$). These subjects, however, did not differ with respect to the number of errors left uncorrected ($F = 2.45$, $p>.05$). Thus, subjects using either

TABLE 3

ANOVA Table for Number of Errors Made

| Source | SS | df | MS | F | p |
|---|---|---|---|---|---|
| MAIN EFFECTS | | | | | |
| Presentation Mode | 13.854 | 2 | 6.927 | 2.445 | .095 |
| Operational Information | 15.812 | 1 | 15.812 | 5.582 | .021 |
| INTERACTION | 9.509 | 2 | 4.755 | 1.678 | .195 |
| RESIDUAL | 175.622 | 62 | 2.833 | | |

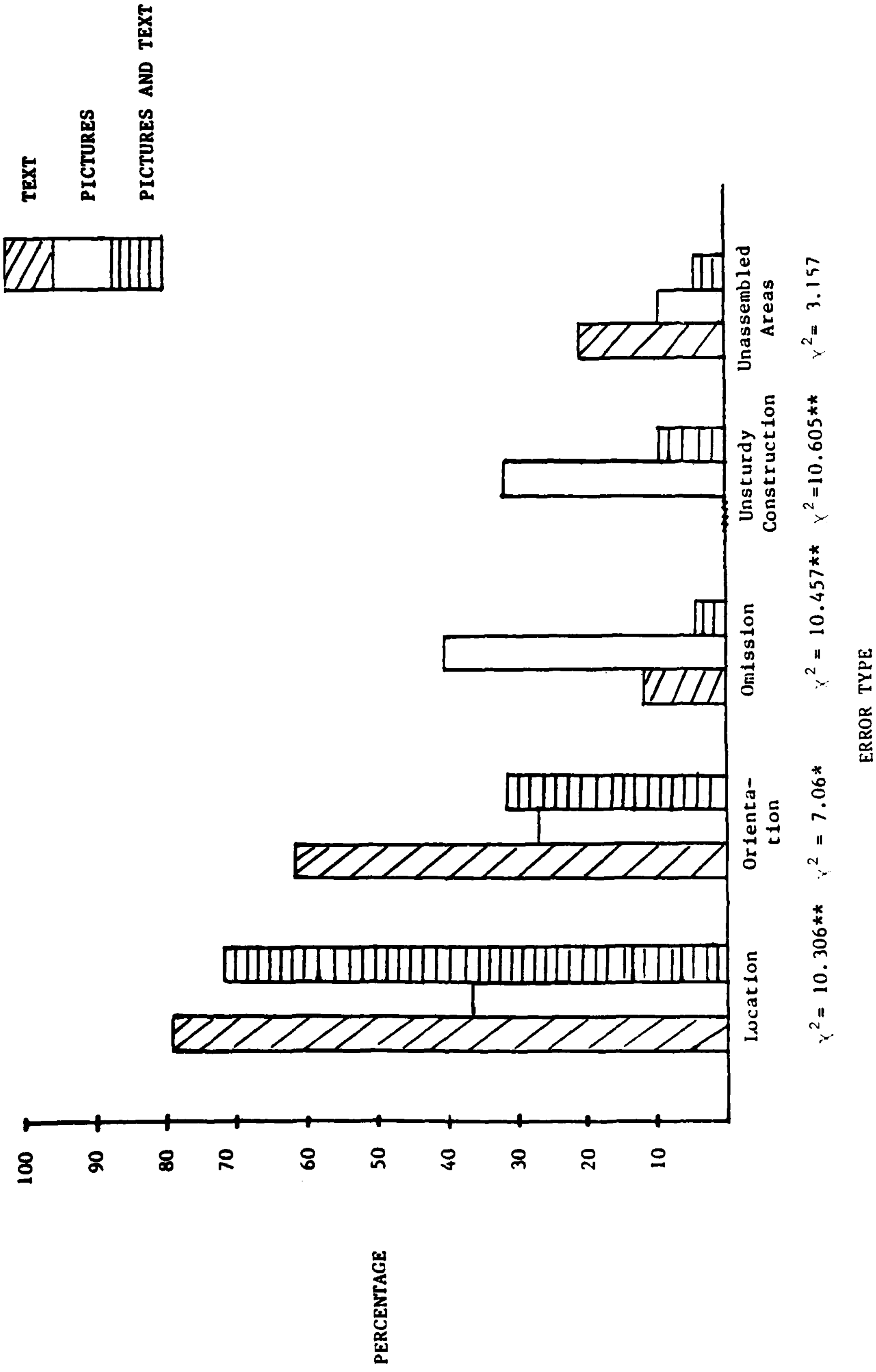
TABLE 4

ANOVA Table for Time to Completion

| Source | SS | df | MS | F | P |
|---|---|---|---|---|---|
| MAIN EFFECTS | | | | | |
| Presentation Mode | 5666843.900 | 2 | 2833421.900 | 22.823 | .0001 |
| Operational Information | 17732.592 | 1 | 17732.592 | .143 | .707 |
| INTERACTION | 742454.930 | 2 | 371227.460 | 2.990 | .058 |
| RESIDUAL | 7697292.600 | 62 | 124149.880 | | |

pictures, text, or a combination of the two, made comparable numbers of mistakes (see Table 3).

There was one way, however, in which the presentation mode affected the accuracy of performance: different types of errors were found to be less prevalent in certain presentation modes. In the present study, five kinds of errors were observed: 1) location or the attachment of parts to an incorrect area of the model, 2) orientation or the placement of parts in the proper location but in an improper orientation, 3) omission or the failure to use all of the parts, 4) unsturdy construction or an inadequate assembly of the parts, and 5) unassembled areas or the failure to build or attach all of the sections of the model. Analyses were conducted to determine whether any of these mistakes was made by a different proportion of college students using either pictures only, text only, or both pictures and text. The results of these analyses, presented graphically in Figure 5, show that significantly different proportions of subjects using the three types of instructions made four of the five kinds of errors. Two of these errors, orientation and location, were found to be made by a smaller proportion of subjects using pictures only ($\chi^2$=7.05, $p<.05$); $\chi^2$=10.31, $p<.05$). While an equally small proportion of subjects using both pictures and text were found to have made orientation errors, the proportion of these subjects making location errors was just as great as those using the text only. Thus, the use of pictures, either with or without text, led to fewer errors of orientation while the use of pictures without text led to fewer errors of location.




* $p < .05$ ** $p < .01$

Figure 5: Comparisons of Error Types

In contrast, a significantly larger proportion of subjects using pictures was found to have made two of the other kinds of mistakes, omission ($\chi^2$=10.46, p<.005) and unsturdy construction ($\chi^2$=10.61, p<.005). Compared with those using the text alone or both the pictures and text combined, a greater percentage of subjects using the pictures alone was found to have committed these two types of mistakes. There were no significant differences, however, for the fifth type of error, unassembled areas.

## Discussion

### Comprehension Monitoring

The results of this study indicate that differences in monitoring activities are observed as students attempt to comprehend procedural instructions. Furthermore, these activities may be categorized according to a taxonomy of comprehension monitoring strategies. It was also found that a number of these activities are related to comprehension.

One kind of activity, however, that did not seem to be associated with comprehension was planfulness. The use of strategies included in this first category of the taxonomy showed almost no relationship to comprehension. In fact, only one of the strategies, involving the selection of parts, was found to be significantly related to either of the two measures used to assess comprehension. College students who were more planful in selecting the parts took longer to finish the task

than students who were less planful. No other significant relationships were found. Thus, students who showed initial planfulness were no faster or more accurate than subjects who were less planful. In addition, while students who were planful in their selection of parts took longer to complete the task, they did not make any fewer errors than students who were less planful in their selection.

One possible explanation for these findings is that planful behavior may not have been necessary to do well on this task. Subjects may have felt that the task was easy enough to accomplish without doing any pre-planning.

In contrast to the results for planfulness, significant relationships were found for two other categories of the taxonomy, ways of following the instructions and detection of errors. For example, examining the second category, the results showed that students who displayed more care either by checking their work or showing a concern for detail made fewer uncorrected errors and took longer to complete the task than those who showed less care. Thus, for these students there seems to be a trade-off between accuracy and time. Careful ways of performing the task may lead to greater accuracy but at the cost of requiring more time to complete the task.

The relationship between detection of errors, the third category of the taxonomy, and performance was slightly different. Students who were quick to detect their mistakes made fewer errors but did not take any longer to finish the assembly than those who were slower to notice their mistakes. There seems to be no trade-off, then, for the strategy

involving error detection. Efficient detection of mistakes leads to greater accuracy but without the additional need of more time.

Thus, the findings suggest that if comprehension of procedural instructions is measured by the time and accuracy of performance, then comprehension will be affected by how carefully the reader follows the instructions and how efficient he or she is in detecting errors. When it is important that a reader comprehend instructions accurately, then strategies involving care in following the instructions and efficient detection of errors should be helpful. However, if accuracy is not crucial and it is more important that a reader comprehend instructions quickly, then strategies involving care in following the instructions should be avoided. Since it is difficult to think of a situation in which readers would not want to follow instructions accurately, it seems reasonable to suggest that they should be encouraged to check their work.

The relationship between the remedial strategies, included in the fourth category of the taxonomy, and comprehension is less clear. While the total number and variety of these strategies were associated with longer times to completion, an abundance of strategies was not associated with greater accuracy. Thus, while the results indicate that students will use a wide variety of remedial strategies when trying to follow procedural instructions, the effect of this monitoring is still unclear.

While such cognitive monitoring is time consuming, it may enable the reader to make certain interpretations about the material. If these

interpretations are not what the author intended to convey, the reader will fail to understand. For example, in the present study, several subjects hypothesized (strategy 6) that the object described in the instructions was a toy car. Since their interpretation was based on an incorrect inference, the models they assembled contained many errors. It was not their poor comprehension monitoring, then, that led to inadequate assembly, but rather a faulty interpretation. Thus, comprehension monitoring can not guarantee adequate understanding. Research on how to make such monitoring effective is needed.

## Effects of Varying the Instructions

The hypothesis that the comprehension of procedural instructions would be aided by the inclusion of explicit operational information received partial support. When comprehension was measured by the number of errors left uncorrected, it was found that, regardless of the mode of presentation, students using instructions containing explicit operational information made fewer uncorrected errors than those using more general instructions. Thus, explicitness of operational information seems to improve the accuracy of performance. This finding supports Bieger and Glock's (1982a) contention that operational information is one of the criterial categories of information contained in procedural instructions.

When comprehension was measured by the time to completion, however, explicit instructions did not have the same facilitative effect. Students who used instructions containing explicit operational

information did not take any less time to complete the assembly than students who used the more general instructions. Thus, while explicitness of operational information improves the accuracy of performance, it does not have the same beneficial effect on the speed of performance. However, since those using explicit instructions did not require any more time to complete the assembly than those using general instructions, there seems to be no disadvantage to the use of explicit instructions. The inclusion of explicit operational information, then, should help to improve both the pictures and text that are used in procedural instructions.

While explicitness of operational detail does not seem to affect the speed of performance, one factor that has been found to influence this speed is the mode of presentation. Findings from the present research as well as those from previous studies (Booher, 1975, Bieger and Glock 1982b) indicate that readers are able to follow instructions quickly when these instructions include or consist of illustrations.

Illustrated instructions may also have an additional benefit. In the present study, for example, the spatial errors of location and orientation were less prevalent when pictures were used. It appears, then, that pictures may be better at communicating spatial information than words. Several reviewers have also commented upon the superiority of pictures in depicting spatial arrangements (Kolers, 1973; Schallert, 1980; Stone and Glock, 1981). Pictures, however, may not be superior in conveying other kinds of information. For instance, in the present study, errors of omission and unsturdy construction were more prevalent

among the groups given pictures alone than among those given either text alone or text in combination with pictures. Thus, information relating to the details of construction seems to be better conveyed by words than by illustrations.

The evidence suggests, then, that when designing instructions one should include both pictures and text if it is important that a reader comprehend these directions quickly and accurately. Furthermore, as discussed above, the operational information contained in these instructions should be made to be as explicit as possible in order to ensure the greatest accuracy.

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